Section H

Nebraska irrigation water resources management

Nebraska is one of eight states that have access to portions of the High Plains Aquifer that extends from Texas to South Dakota. *Figure H-1* shows the saturated thickness of the aquifer, with Nebraska having a substantial area with blue colors on the map that indicates over 600 feet of saturated thickness. In total, over 65% of the water stored in the aquifer is located inside the Nebraska borders. Some areas of the Sandhills can reach saturated thickness of 1,200 feet or more. The High Plains Aquifer supplies irrigation water to over 8.9 million acres of Nebraska farmland. However, as the map indicates the saturated thickness varies greatly across the state and water mining has lowered groundwater levels in excess of 100 feet in some areas of the state.

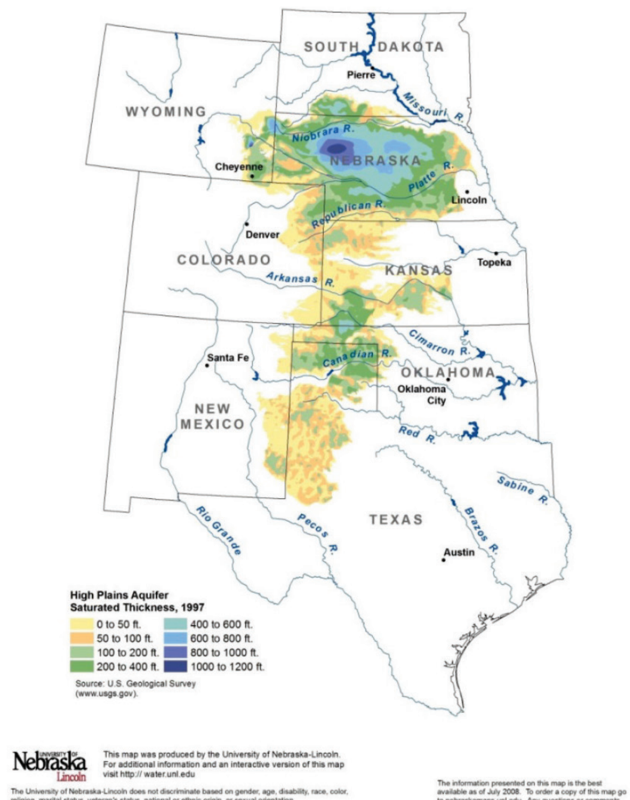

Figure H-1. Map of the saturated thickness in the High Plains Aquifer formation across eight states ranging from Texas to South Dakota.

Nebraska experiences a broad range of annual precipitation, from over 34 inches in the far southeast to less than 15 inches in the far west (*Figure H-2*). In general, annual precipitation decreases 1.0 inch for every 25 miles traveled from east to west. This range in precipitation places the state in climatic zones ranging from subhumid in the east to semiarid in the west. As a result, the need for irrigation increases substantially as one travels west across the state. Of the over 8.9 million irrigated acres of cropland, over 80% of the irrigation water is applied using center pivot irrigation systems.

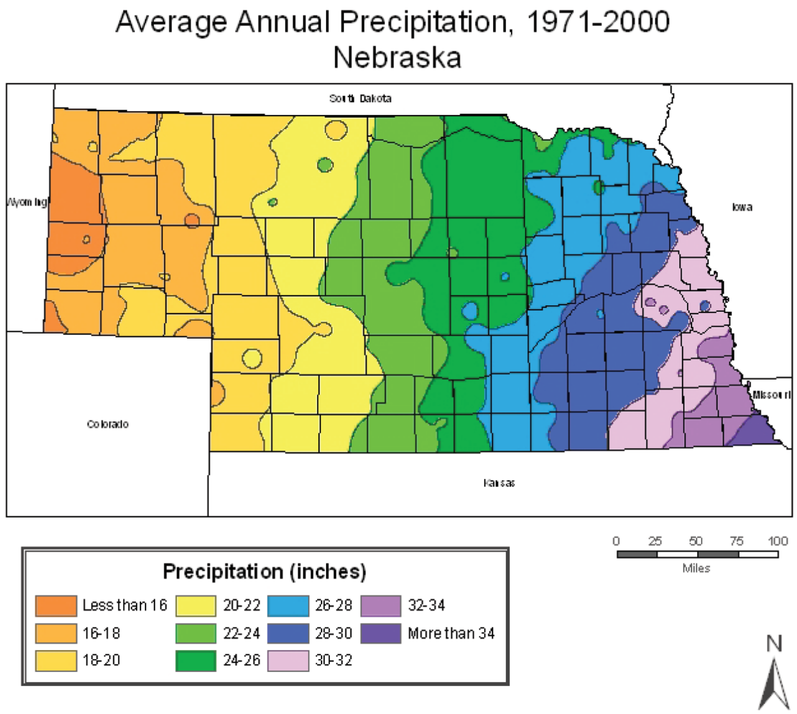

Figure H-2. **Range in long-term average precipitation across Nebraska.**

To understand water use it is helpful to consider the fate of water as depicted in the hydrologic cycle (*Figure H-3*). Within the earth's atmosphere there is a constant amount of water; however, the supply of water is continuously recycled when viewed from a global perspective. Precipitation that reaches the earth's surface either infiltrates into plant root zone, runs off to streams and rivers, or is intercepted by plants. Some of the water that infiltrates is used to supply water that evaporates from the soil or that transpires through plant leaves. When more water infiltrates into the soil than plant root zones can store, the excess infiltration flows through the soil toward the groundwater aquifer. Water that reaches the groundwater is usually called recharge. Recharge causes the local groundwater level to rise, which can develop a gradient resulting in groundwater flow away from the recharge area. Groundwater may flow toward streams, lakes, and rivers if groundwater aquifers are connected to the stream. In other cases the elevation of the stream may be higher than the groundwater surface and water may flow from the stream to the groundwater. Water also reaches streams and lakes by direct overland runoff.

Water in streams and lakes can come from either surface runoff or groundwater (*Figure H-3*). The contribution of flow due to groundwater is frequently called base flow. Energy from the sun and dry winds causes water in streams, lakes, and the ocean to evaporate into the atmosphere. Similarly, water evaporates from soil and/or transpires from plant leaves. The return of water to the atmosphere as water vapor is referred to as evapotranspiration, abbreviated as ET. Water vapor in the atmosphere condenses as it cools and returns to the earth as precipitation. **The hydrologic cycle is the continuous process of converting water into different states and transporting from one location to another.**

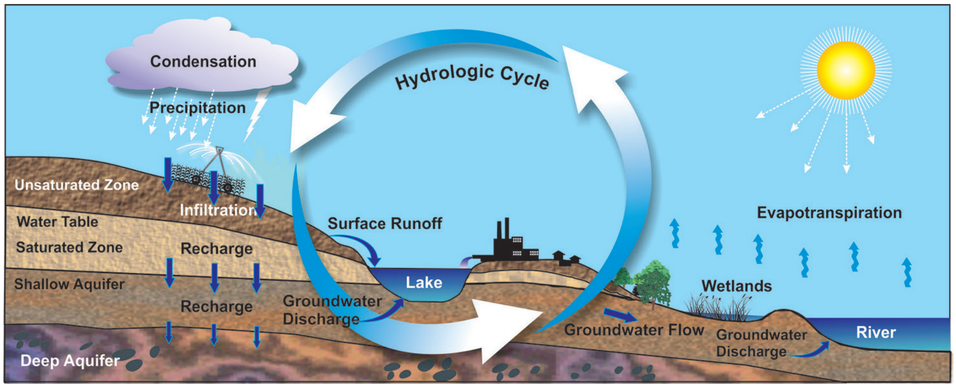

Figure H-3. Diagram of the hydrologic cycle (source *www.sws.uiuc.edu/docs/watercycle*).

The approximate water balance for Nebraska is depicted in *Figure H-4*. On average the state is a net exporter of surface water with 1.4 inches per year more exiting the state than enters. Annual precipitation averages 22.6 inches of which soil evaporation and plant transpiration deliver nearly 20 inches back into the atmosphere. Electric power plants and other relatively small water uses return approximately 1.3 inches of water to the atmosphere per year.

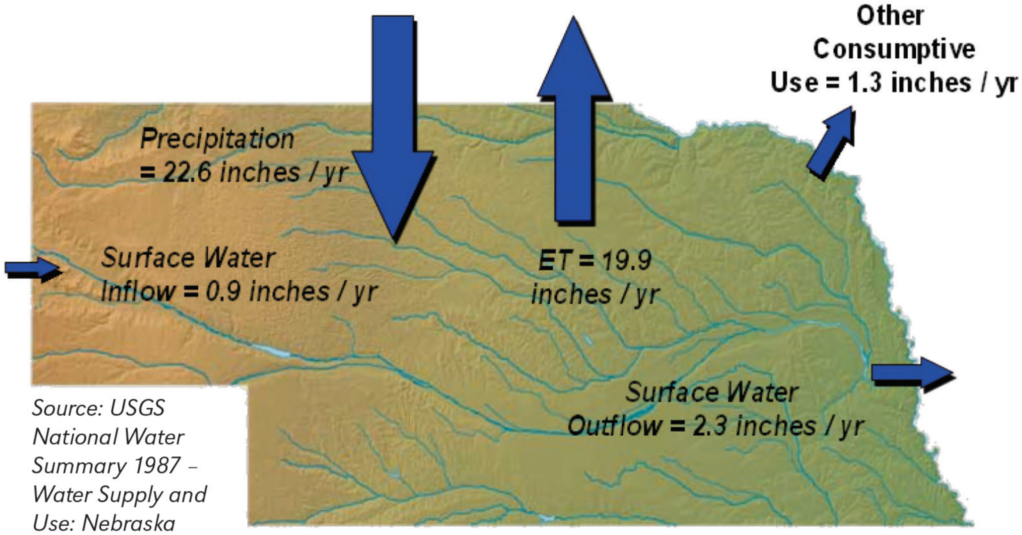

Figure H-4. Approximate statewide water balance for Nebraska.

Watersheds

Though most people think of watersheds on a local scale**, a watershed is the land whose runoff drains into a particular stream** (*Figure H-5*). All land uses in a watershed affect the overall water balance of the watershed and surrounding regions. Many processes included in the hydrologic cycle also apply to the watershed. The primary difference is that water vapor as evapotranspiration generally does not return to the same watershed where the ET occurred. Thus, evapotranspiration represents a loss for the watershed. In the Great Plains, the jet stream transports air from more arid regions into the watershed, and the evapotranspiration that occurs is often transported toward more humid regions.

Precipitation is the primary source of renewable water supplies for most watersheds in the Great Plains. Some watersheds benefit from inflow from surface water in streams and rivers from upstream regions. Groundwater may also flow into the watershed area. Precipitation and inflow to the watershed produces outflow (streamflow or groundwater discharge) or evapotranspiration within the watershed. Some water is also temporarily stored within the watershed as water in reservoirs or groundwater aquifers. Water is also stored in the unsaturated soil (i.e. the root zone and the vadose zone) above the groundwater aquifer. Water in storage can increase or decrease over time depending on the balance between inflow, outflow, and evapotranspiration.

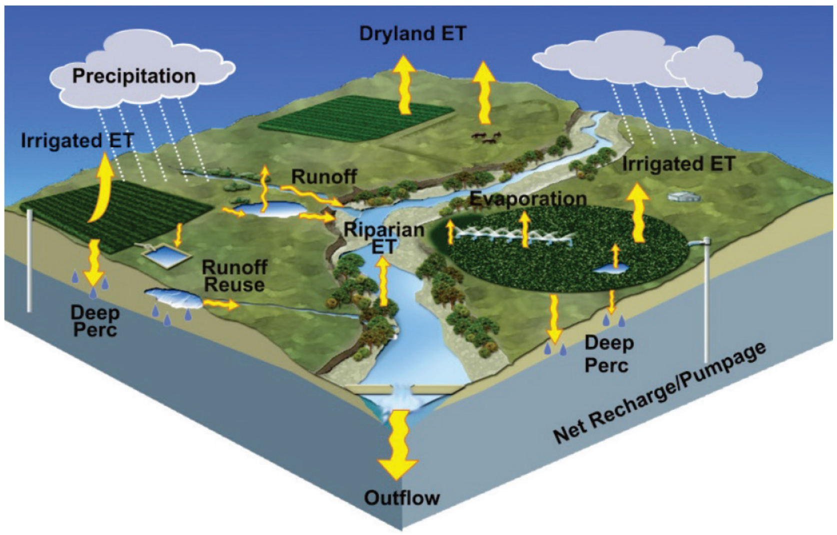

Figure H-5. Diagram of the major water balance components of a typical agricultural watershed.

Man can affect the hydrologic cycle and the water balance of a watershed by diverting surface water from lakes or streams, and by pumping groundwater. Some applications, such as irrigating crops, increase evapotranspiration. The increase in evapotranspiration due to irrigation is the called the consumptive use of irrigation water and represents a conversion of liquid water to water vapor that ultimately leaves the watershed. Some of the water diverted from streams or pumped from groundwater for irrigation may percolate through root zones of irrigated fields or seep from water delivery systems. Seepage and drainage usually recharge the groundwater aquifer. Some water may run off irrigated fields or may be spilled from delivery systems. If the runoff and/or spills flow to a stream or lake, the water is usually referred to as return flow because it becomes available downstream.

Water use

We generally think of diverting water from streams or reservoirs, or pumping from groundwater, to supply an intentional use. Evapotranspiration that occurs due to natural activities is not generally considered to be a "use." Thus, evapotranspiration from native range or evaporation of natural lakes would not normally be referred to as a use. The act of moving water from its original location to a different location or time (i.e., "using the water") has an intended purpose. For example we irrigate to reduce water stress during dry periods to sustain crop yields. We might also use streamflow or groundwater to cool electrical power generation systems or to produce ethanol. When we "use" water, we generally increase evapotranspiration.

Not all of the water “used” is consumed (i.e., converted from a liquid to water vapor). For example, consider the sprinkler and surface irrigation examples shown in *Figure H-5*. Water supplied to the irrigated field as either precipitation or irrigation furnishes water for crop evapotranspiration, but may also result in runoff that may return to the streams of the watershed or may percolate through the crop root zone and recharge the groundwater aquifer. Thus, the amount of water pumped for irrigation is not all consumptively used. Data from the USGS (2005) lists the relative consumptive use of water by major sectors in Nebraska. The data show that up to 90% of the water consumed in the state is for irrigation. Cooling of power plants represents approximately 8% of the total consumptive use in the state. The USGS report indicates that, in Nebraska, relatively little water (<10%) is consumed for domestic or municipal uses.

Consumptive use

The meaning of consumptive use is often different among individuals, especially those that are new to hydrologic processes. Various scientific and engineering organizations have developed definitions for **consumptive use** that vary slightly, but that usually have a consistent message. The United States Geological Survey defines consumptive use as **“that part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.”**

Consumptive use is more subtle if we alter the land use and/or agricultural production practices. For example, it is widely recognized that reduced tillage contributes to higher infiltration rates that supply water for crop evapotranspiration and groundwater recharge. The increased evapotranspiration diminishes the amount of runoff that contributes to streamflow leaving the watershed. So, as one compares practices from earlier times, the changes in farming practices could represent an increase in consumptive use. However, the individual producer did not intentionally move water from one location to another in this process, so in that sense there may not be an increase in consumptive use even though it results in an increase in evapotranspiration.

Some consumptive use may be beneficial in that it increases crop yields and profitability, allows for production of electrical energy or provide for increased recreation at lakes, or provides for some other purpose. In other cases consumptive use may be nonbeneficial. Examples of nonbeneficial uses would be evapotranspiration from weeds in road ditches that are wetted due to uncontrolled runoff from irrigated lands, evapotranspiration from artificially wetted areas adjacent to irrigation canals, or evaporation of water from agricultural fields, water surfaces, streets, and pavements. The fate of an irrigation water withdrawal relative to these considerations is illustrated in *Figure H-6.* Identification and reduction of non-beneficial uses of water offers potential to enhance water supplies with little loss of economic or environmental impact.

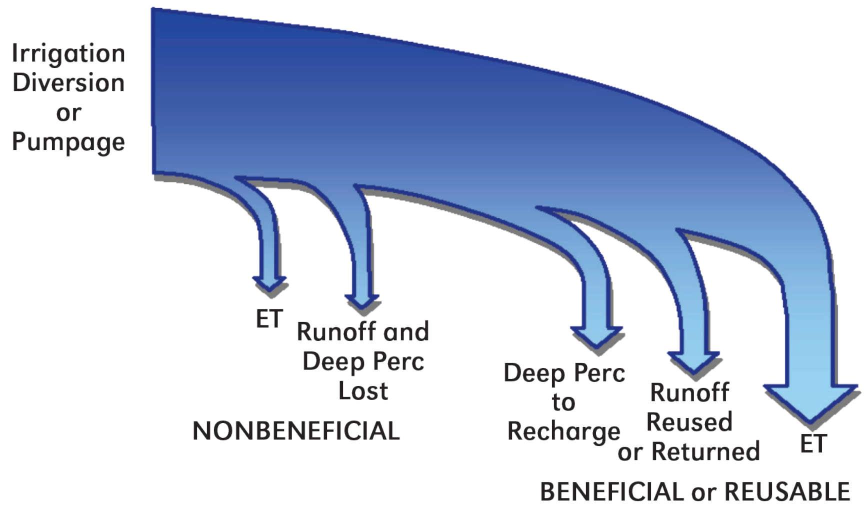

Figure H-6. Schematic drawing of the possible fate of water used for irrigation.

Farm scale

Water use at the farm or field scale differs slightly from considerations at the watershed scale. The fate of water for an irrigated field located in a watershed is illustrated in *Figure H-7*. The rectangular dashed line represents the water balance for an irrigator. Additions to the field water balance include precipitation, and irrigation water from ground or surface water sources. In some cases a high groundwater table can be considered as a water addition to the field water balance. Losses of water from the field are represented by surface runoff, deep percolation and evapotranspiration from the field, and evaporation from on-farm storage or water conveyance systems. Lateral flow of groundwater leaving the watershed can also be a loss. Farmers profit by increasing efficiency to obtain as much evapotranspiration by irrigated crops as possible. Thus, runoff, deep percolation, and evaporation from storage are seen as losses of water. Water that percolates from the field or that runs off and returns to the stream would not be seen as a loss to the watershed as the water is still in the system for use elsewhere.

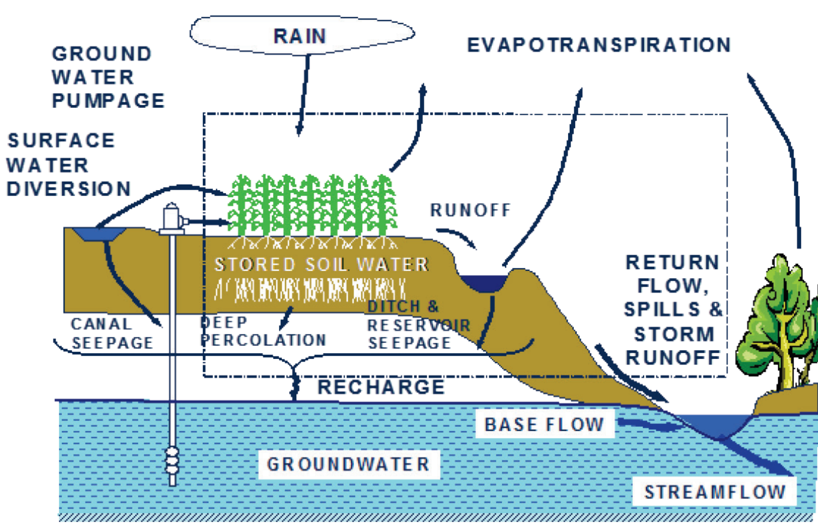

Figure H-7. Diagram of water balance for an irrigated field supplied with ground and surface water for irrigation.

Application of water from an irrigation system can result in several outcomes as illustrated in *Figure H-8*. The goal of the irrigator is to produce the maximum of crop ET from the irrigation as it is generally linearly related to crop yield as shown in *Figure H-9*. Irrigators can improve their efficiency by a range of activities and management practice changes. Actually, the only truly beneficial use of water for the field manager is transpiration from crop leaves. However, it is difficult to separate the transpiration from soil evaporation, so evaporation is included with transpiration as a beneficial use. Reduced tillage and other practices that reduce evaporation from the soil reduce consumptive use without reducing transpiration. This can reduce the amount of water that must be extracted from the source to fully irrigate the field.

Improving irrigation efficiency can reduce the other surface water losses and recharge and/or return flow to streams as shown in *Figure H-8*. Practices that reduce surface losses will reduce nonbeneficial consumptive use. Irrigation water that goes to recharge and/or return flow represents losses to the producer, but not to the watershed per se. Thus, improving irrigation efficiency will usually leave more water at the ground or surface water source, and may reduce nonbeneficial use. Extracted (pumped or diverted) water that is recycled back to the aquifer or stream is not a loss to the watershed, thus improving irrigation efficiency will not "save" all of the reduction in extraction that was accomplished through improved irrigation efficiency.

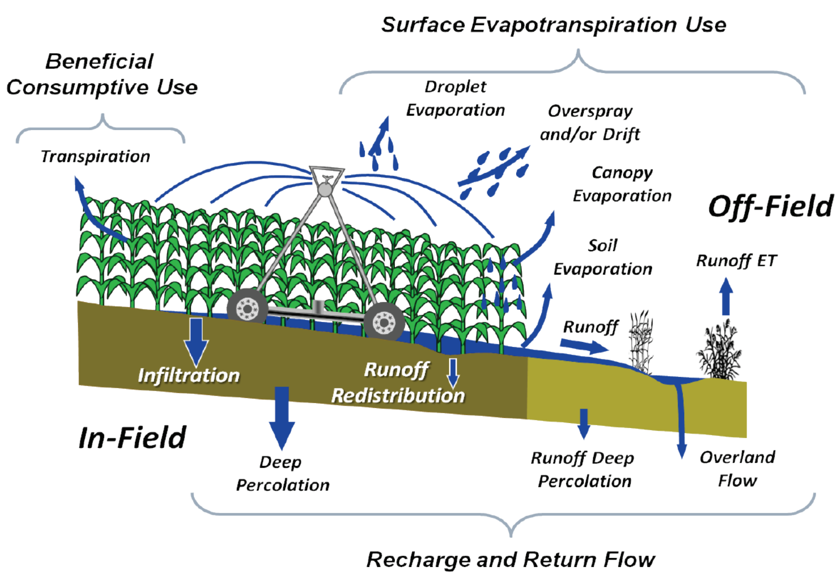

Figure H-8. Water balance components for irrigated cropland.

Deficit irrigation can also affect crop water use and yield. Deficit irrigation is the intentional stressing of the crop at certain crop growth stages to reduce water use while minimizing yield reduction. The process of deficit irrigation is illustrated in *Figure H-9.* We normally find a linear relationship between crop yield and evapotranspiration (ET) from the crop for most crops that are raised in the Great Plains. The relationship between irrigation and yield for an efficient and inefficient irrigation system is also shown in *Figure H-9.* The curves show that a portion of the irrigation water is consumed for ET while the rest goes to other surface losses, recharge, or return flow. If the yield is the same for an efficient and inefficient irrigation system the crop water use will be the same but the nonconsumptive uses will be larger for the inefficient system. If the amount of irrigation water is limited an efficient irrigation system will generally produce more yield and will result in more in-field consumptive use than a less efficient system. *Figure H-9* also illustrates that irrigation systems become more efficient, i.e. a larger portion of the applied water will go to ET, when deficit irrigation is employed.

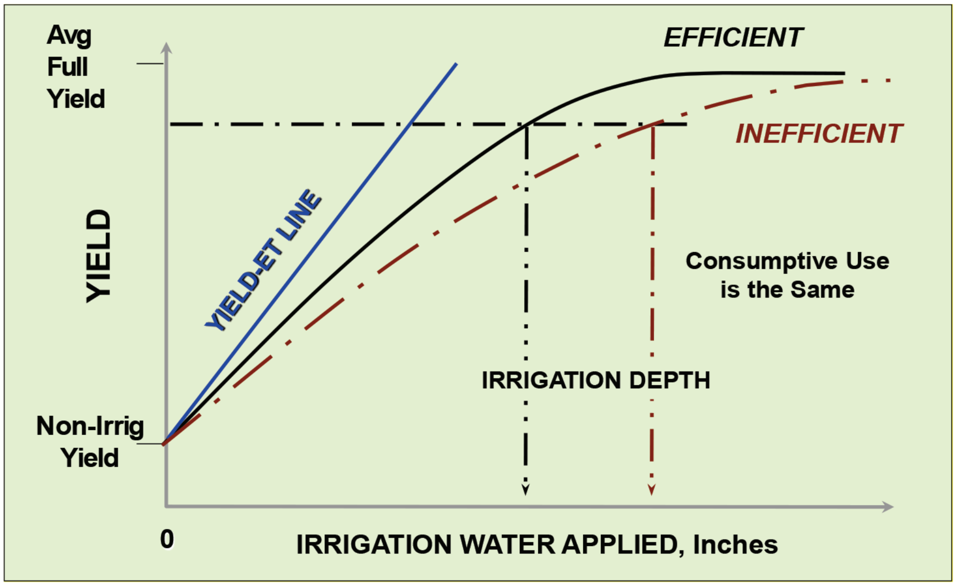

Figure H-9. Effect of improved irrigation efficiency on in-field water use and yield.

More Extension Publications (available at ianrpubs.unl.edu)

EC732, Irrigation Efficiency and Uniformity and Crop Water Use Efficiency

RP195, Targeting of Watershed Management Practices for Water Quality Protection